TECHNOLOGY DEPT.

INSTITUTE OF PETROLEUM REVIEW

VOL. 7 No. 83 NOVEMBER, 1953. Price 1/6d. Annual Subscription: Fifteen Shillings

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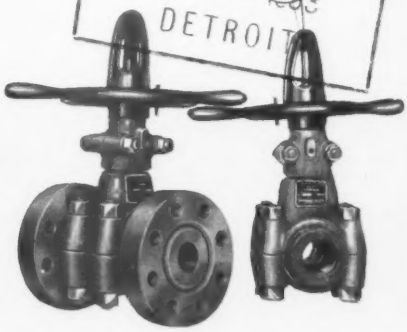

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No. 83 NOVEMBER 1953 Vol. 7

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SOME DESIGN PHILOSOPHY AND ENGINEERING PROCEDURE IN PETROLEUM PLANT CONSTRUCTION*

By R. C. FISHER (Fellow)

Engineering procedure in regard to the petroleum industry is essentially identical with that in general chemical engineering, but it is very different from the approach held by other branches of engineering. The reason for this is that petroleum engineering in particular, and chemical engineering in general, must cover a great variety of heterogeneous subjects, whereas in other branches it is often possible to concentrate to a much greater degree on a limited number of aspects. The corollary to this difference is that frequently, in petroleum and chemical engineering, it is not possible to penetrate in one's study to the same depth as is often done in other engineering branches.

The marked difference between petroleum engineering and other branches of engineering in this respect, is that such studies as can be carried out must cover a much broader field than purely mechanical and physical considerations. The nature of the problems necessitates a detailed study of the material, both regarding products and equipment. Corrosion problems and metallurgical investigations, both possibly not strictly engineering aspects, are of controlling importance. Usually large sections of the design are dictated by the above considerations and frequently designs have

*Summary of paper read to the London Branch on 27 April 1953.

to be adopted which, from a strict engineering point of view, are not satisfactory, but there is no alternative because of the material aspects involved.

The historical development of petroleum engineering was rapid and, like the early beginnings of other industrial developments, was on a purely empirical basis. Heat economy, fractionation, and economic measures in chemical treatment only gradually entered the field. Batch-wise operation gave way to continuous processing. Vacuum operation and separation under pressure are amongst subsequent developments. Separation by solvent extraction, absorption, and adsorption are relatively new.

Theory and Practice

Petroleum engineering can still be considered as a relatively junior branch of engineering, in spite of the fact that the days when it was either an art or a craft lie far behind us. One symptom which may be regarded as contributory evidence for the claim that petroleum engineering is approaching the status of a science, may be seen in the decreasing use of the phrase "This may be correct in theory but it is wrong in practice."

The most cursory analysis of the above statement proves the thoughtlessness and inherent contradiction of the thesis. A correct theory, in the majority of cases, is an interpolation between and an extrapolation of experimental facts and the endeavour to co-ordinate them on a rational basis. Therefore a theory cannot be in contradiction with its basis. In many cases, the person who rejects theory is either incapable of abstract thinking or, alternatively, has no confidence in it because of previous failure, which seldom is caused by the theory itself.

The man who accepts exclusively tangible laboratory experiments and observations of the functioning of equipment, without resort to theoretical considerations, is faced with a multitude of heterogeneous facts without being able to crystallize in his own mind a broader underlying principle. He cannot draw on generalizations procured in allied fields and is frequently groping in the dark and must rely on haphazard findings. Furthermore, he may well proceed in his search for a solution along avenues which are in contradiction with well-established and undisputed principles.

The classification of petroleum engineering as a branch of chemical engineering, as detailed above, is in line with common and accepted nomenclature but the general group is more properly referred to as physical engineering, as mentioned later.

Conjecture and Facts as Design Bases

Even if the tools of physics and chemistry (in the widest sense of the terms), are far from being complete and satisfactory, nevertheless the modern engineer will not reject all the conclusions drawn from pure conjecture and hypothetical surmise. The fact that the actual problems he has to deal with are frequently beyond available knowledge and experience, forces the modern engineer to resort to an apparently less safe basis on which to build his structure.

It is, however, unwise to speculate on matters which are already known, and in this connexion presumably a large amount of errors are committed. It is hardly possible for the individual to be familiar, even on broad lines, with all available tools, and frequently the time at our disposal for a certain job does not permit the acquisition of such available information, even when it is known where to find it. Nevertheless, it must be the endeavour of the petroleum engineer, especially if he belongs to the younger generation which enjoyed a better basic training than was available to those who have been in the industry for some years, to use in his reasoning a maximum of known facts. It is frequently the younger generation

that produces the basic work, whereas their superiors, for other reasons than the ones referred to above, have little opportunity of substantially contributing towards the basic design, to say the least with reference to detail engineering.

In the petroleum industry, in common with practically all human effort, the fascination lies in the work that can be done and has to be done on the "borderland of the unknown," but it is important to bear in mind that a complete oil refinery is built by the effort of a very small number of leaders and a vast number of co-workers. In order to reach the domain of the most fascinating work, very much territory must be covered beforehand, and the roads that lead through that territory, as far as petroleum engineering is concerned, are called physics and chemistry. The universal tool for the manipulation of these sciences is mathematics. Classification of mathematics as a tool does not imply that this science is on a lower level than physics and chemistry. It simply means that mathematics in engineering does not play the leading part which these natural sciences do, but the part of the servant who is, however, "a torch-bearer marching in front, rather than a train-bearer following behind." If this statement is accepted, there is no emphasis needed on the demand for the maximum possible knowledge in this connexion.

Set-backs

When set-backs are investigated, it is surprising how often, after the event, it becomes apparent that the cause of failure is due to a disregard of basic principles. This realization is frequently aggravated by the fact that the ignored principles are not hidden and remote issues but more often simply basic and well-known rules.

Classification

As a general definition, petroleum engineering might be accepted as a branch of engineering concerned with the development and application of processes in which chemical and physical changes of petroleum and its derivatives are involved. Practically all materials are processed in fluid form, *i.e.* either in the liquid or gaseous phase. The solid phase appears only in a relatively small field and applies to rather specialized processes. The work of the petroleum engineer covers design and construction of equipment and in some degree the operation of the plant.

Unit Operations and Chemical Treatment

The physical aspect can be subdivided in broad groups, conventionally referred to as unit operations, such as fluid flow, heat transfer, evaporation, absorption and adsorption, extraction, and so on. The chemical aspect in petroleum engineering occupies a relatively small field, and even there it is frequently a matter of opinion whether the particular process should be classed as chemical or physical. Under the heading of chemical reactions come the refining of petroleum products, cracking, polymerization, and so on.

In the majority of cases the problems facing the petroleum engineer are not connected with the processes as such, but with the means of translating a successful process into industrial form. Selection of suitable materials of construction, suitable design of equipment, particularly if this involves very small or very large items, are his primary concerns.

When reviewing the above classification a basic difference between petroleum engineering and other branches of this science is not apparent in a paramount way. It is the approach to the problem rather than the method of solution which is characteristic of petroleum engineering, and this, with very few exceptions, proceeds as follows:

The Material Balance

The material balance is the basis of all calculations. As far as petroleum engineering is concerned the law of

conservation of matter still holds rigidly, and any recent modifications to this concept do not affect the work at the present. Material balance is used in connexion with the design of the individual pieces of equipment, as well as in connexion with the plant as a whole, and in a wider sense, in particular in connexion with economic considerations, the material balance includes also the outside sources and receivers of the material.

Nomenclature and Measurement

A complication which frequently arises in the petroleum industry results from the unfortunate heterogeneity of nomenclature and units of measurement used. Not only different systems are used, but very often, in any one system, units are expressed by elements that belong to other systems. Furthermore, some basic units used in petroleum engineering are not integer multiples of each other, and in addition, different units are used for measuring the same property, depending on the physical state of the measured quantity.

The Energy Balance

The next analysis applies to the energy balance and here again the law of conservation of energy, *i.e.* the first law of thermodynamics, is considered to hold rigidly. The practical difficulty in connexion with the energy balance as compared with the material balance is the fact that in the material balance a relatively accurate account is usually not difficult, whereas in the energy balance the percentage of unaccountable or uncertain losses may be so high that they substantially influence the accuracy of the result. In this connexion frequently empirical factors, sometimes of a highly questionable character, have to be used.

The Static Equilibrium

The basic principle governing the static equilibrium of the physical and chemical processes is the second law of thermodynamics, and here, fortunately, no reference has to be made to modifications introduced by recent developments. This law, being derived from a statistical basis, is in essence a probability law, which does not involve the basic causes of events and should be therefore immutable for all items.

In petroleum engineering the entropy diagram is used to a large extent, possibly more than in any other branch of engineering that deals with thermodynamic processes. The industries concerned with power generation and refrigeration also use the entropy diagram to a great extent, but the former is concerned only with steam entropy diagrams and the latter with the entropy diagrams of a limited number of refrigerants, whereas the petroleum industry has to make use of the entropy diagram for a very large number of hydrocarbons. In addition to that, the petroleum engineer is also interested in the Mollier diagram for systems comprising two or more components.

Other aids to calculations frequently used in petroleum engineering are dimensional analysis and non-dimensional correlations. These approaches are most frequently used where there is no sufficiently rigid theoretical basis, and therefore it is necessary to resort to a combination of rather primitive basic equations and qualitative relations combined with quantitative experimental data. Under this heading come the frequently used diagrams for heat transfer, pressure drop, mass transfer, and so on.

The Transfer Rates

The rate of transfer of mass and conversion of energy, although a very important item, has a relatively restricted rôle in common petroleum engineering. The great majority of processes, such as fractionation and chemical treatment, make little or only empirical allowance for the time rate, and it is generally assumed that the equilibrium state, as

dictated by the physical and chemical variants of the reaction, is reached instantaneously. Problems involving time reaction are essentially connected with processes involving molecular changes.

The mathematical analysis used in this type of investigation is often rather primitive and it is frequently impossible to use the known theoretical correlations, due to the complexity of the problem.

The Economic Balance

The last item in this enumeration, but by no means the least important one, is the economical balance. Studies in connexion with it indeed cover all aspects of petroleum engineering. It refers to materials of construction as well as to the dimensioning of the equipment. It includes the quality, quantity, and cost of the raw materials as well as the products. It covers the location of the plant as regards geographical, social, and market conditions. The soundness of the economic analysis may indeed prove the paramount item responsible for success or failure of a proposition.

The method of establishing the economic analysis for petroleum projects is, in principle, not different from similar investigations in other fields. However, the petroleum industry requires the use of very specific factors in the calculation. For instance, the rate of depreciation is very high; sometimes an amortization of only two years is required.

Another specific consideration is that the prices of raw materials and products are generally dictated by the policy of the oil companies, and a forecast of what the price pattern will be when the plant comes into operation is not easy.

The Practical Procedure

The foregoing description of design philosophy should form the basis from which the modern petroleum engineer approaches his task. The subsequent considerations which refer to engineering procedure can best be reviewed against the general history of a project.

The object of any plant is the conversion of lower value materials into others of higher value. It is obvious that "value," in this connexion, can only have relative meaning, referring to specific backgrounds of supply and demand.

In the majority of cases the basic thought for the construction of plant does not originate with the petroleum engineer. The usual procedure emanates from market research, or similar investigations, which reveal and justify the construction of a process plant.

The Preliminary Design

At this early stage the major function of the design engineer is to obtain from the laboratory the production of all, or the majority, of data which will subsequently be needed in designing and construction. He should also concern himself with matters related to the accuracy of the data obtained and then, from his experience, apply the necessary safety factors to be used in connexion with the laboratory results.

After this first phase, the petroleum engineer prepares a very general design of a commercial plant, which reveals, on broad lines, the major dimensions of the equipment involved and also permits him to make a rough assessment of cost of equipment, utilities consumptions, and so on.

It is at this juncture that economic considerations enter conspicuously into the work of the engineer, and in no phase of his subsequent work must they be allowed to recede into the background. Whether the object of a specific study or a sub-conscious reminder, they must remain the guiding light in his work.

Only on rare occasions is the plant of such nature that not much use can be made of information from similar plant constructed in the past, and for this reason it is of the utmost importance

that the petroleum engineer has at his disposal, in a readily available form, reports of experience collected from previous work. Reference to the technical literature is a very powerful weapon in his armoury. A particularly useful tool of co-ordination is an up-to-date card index system, suitably cross-referenced.

Incidentally, a complication which nearly always arises when utilizing experimental data for plant design is the fact that, in many cases, the research work is done on batch-wise operations, whereas the industrial plant is usually intended to work continuously. Unfortunately, continuously working laboratory apparatus, although most desirable, is expensive, and furthermore, rather inflexible regarding rearrangement of equipment and variation of process variables.

Laboratory Investigations

Frequently the laboratory research in connexion with the original conception of a process may have been carried out on rather arbitrary operating conditions regarding pressure, temperature, and other process variables, but the petroleum engineer's initial analysis may show that a modification of these process variables would result in a more favourable design without affecting the ultimate objective.

In many cases it may be necessary to deviate from the most favourable conditions regarding quantity and quality of products produced, in order to arrive at an overall optimum for the project as a whole. In such cases back reference to the research workers may be necessary and additional work on their part is called for.

The Pilot Plant

In cases where a major plant is involved, or where the plant under consideration is a prototype for series production, or because a substantial number of novelties are introduced in the design, it may be advisable to construct a pilot plant on a semi-commercial scale. Such plant usually yields valuable information also on economic considerations and the results from a pilot plant much closer simulate larger-scale operations than those from laboratory equipment.

An important reason why pilot plant research is not frequently carried out is the cost connected with such work. Not only the actual cost of the plant may be prohibitive, but also operation of the plant, scope and method of instrumentation, and other aspects are highly specialized for this type of work, and the necessary personnel may not be available in the organization of the engineering contracting firm. It is not infrequent that pilot plant research is carried out by the client himself rather than by the contractor, in which case a considerable burden is removed from the contractor's shoulders.

A very important item in this connexion is investigation referring to metallurgy and corrosion. This aspect has become particularly involved in recent times, because not only has research produced a vast amount of different materials of construction from which to choose, but on the other hand, the market availability of such material is often a severe restriction on the choice.

The Detailed Study

After pilot plant research has produced the necessary process design data, an appraisal of the mechanical design features follows. This embraces selection of suitable material and investigation, on broad lines, of the mechanical strength of the equipment.

All the preceding investigations produce the general characteristics for the project, and it is then decided whether to proceed with a detailed study and the compilation of a cost schedule.

Unfortunately, the procedure outlined above cannot always be followed in industrial practice. Also, due to the

competitive basis on which work takes place, very appreciable duplication of investigations occur, often to the detriment of all concerned.

Calculations, including dimensioning of equipment, heating surfaces, line diameters, tower diameters, number of fractionating trays, and so on, follow. After all the necessary technical information has been compiled and transmitted in suitable form to the drawing office, the major part of the work can commence. This comprises preparation of drawings, specifications, and requisitions for material and equipment.

Simultaneously with the drawing office work, procurement activities must commence, and it is in this connexion, that appreciable savings in time can be effected by careful planning and forethought. Frequently, bulk purchase of raw material and proprietary articles can be made long before the respective drawings and requisitions are completed or the actual quantities are known in detail. Only considerable experience in this respect ensures efficient procedure.

The Work on Site

The end phase in petroleum engineering is the work on site. It is here that is found the most pronounced difference between petroleum practice and other sections of chemical engineering. Construction technique has been specialized to such a degree, that knowledge and experience gained elsewhere, is only of limited value. This remark applies both to detailed assembly procedures, such as welding, as well as to the fact that size and weight of equipment is often on a scale not normally encountered in general chemical engineering.

The first steps in constructing a petroleum refinery are soil research, site preparation, which may include levelling and clearing of the ground, and, where necessary, the construction of temporary road and rail facilities.

Foundation Problems

As mentioned previously, equipment in the petroleum industry includes usually items of considerable weight and height, which frequently necessitates the use of piles, although rafting and simpler forms of foundations are used on a considerable scale. Trenches and ducts for the drainage system have to be built, foundations for storage tanks must be constructed, and permanent roads and other civil engineering work have to commence at this stage.

It is surprising to notice the divergency of ways that are used for solving civil engineering problems in general, and foundation problems in particular, *e.g.* the construction of tank foundations, which range from primitive "sand bedding" to very elaborate and specialized designs.

Erection of Equipment

Erection of the process equipment is the most difficult phase of the construction work. This particularly refers to cases where the erection has to take place in existing refineries, and where processing work elsewhere, must be maintained during the erection period of the new plant. In such cases careful study of the problem, how to bring the equipment to site, and how to erect and fix the necessary erection tackle is imperative.

Many contractors, particularly in the U.S.A., resort to the use of plant models, which cover not only the equipment of the new plant but also all existing equipment surrounding the erection site. Such studies then permit the choice of the best way of transportation of equipment, the location of deadmen for the guy-ropes, and many other features, which are not easily appraised without the aid of models.

The erection of steelwork and storage tanks does not usually present a particular problem, and is carried out together with the erection of the process

equipment, which may take precedence in the erection programme.

Installation of the pipework often involves the biggest part of work on site. Assembly of the pipework, fabrication on site, and the interconnection of the equipment by the pipework constitute this phase. The laying of electrical cables also takes place in the latter part of the construction programme. At this stage, particularly careful planning of the overall and detailed procedure is of paramount importance.

The end of the construction period covers thermal insulation of equipment, fire-proofing, painting, as well as mechanical and hydraulic testing of plants.

The Off-site Facilities

The off-site facilities comprise the general piping, pumping, and loading installations. The auxiliary plants for the production of utilities, are naturally included in the construction programme.

Plant Operation

The operation of the commercial plant is not usually the direct responsibility of the design and construction engineer. The running of the plant is, as a rule, entrusted to a specialized operating staff, which has not been connected with the previous phases of the work referred to above. Nevertheless, the interest of the design and construction engineer should not terminate with his activities at headquarters and wherever possible he should be given an opportunity to study plant operation and to learn from his successes or mistakes.

The Engineer as an Individual

This review is not intended to present a programme for the petroleum engineer's activities, nor to summarize available knowledge, but it is an endeavour to outline in a detached way the mental approach to those problems arising in the petroleum field, and therefore a reference to the individual, who indulges in these activities, may be of some interest.

The industry comprises a highly integrated effort and the individual worker must consider himself as a member of a team. This implies that well organized co-operation forms the premise of success. It is also generally accepted that only a few engineers who enter the petroleum field feel beforehand a specific interest and have a particular qualification for the work. The great majority of successful workers are developed in their professional career by meeting the problems and concentrating on same, and also through co-operation with their co-workers. Petroleum engineering is not a field where all knowledge is contained in the executive professional organization, but the degree of separation between general knowledge and specific knowledge is considerably greater than in other branches of engineering. The fact that, in spite of the endeavour to develop petroleum engineering into scientific procedure, it is still necessary to rely to a large extent on empirical information, is the reason why the newcomer entering the profession must participate in work for which his education may constitute only a relatively small asset.

Fortunately, this situation in the U.K. is changing for the better. Firstly, because academic training for petroleum engineering is being developed, and, secondly, because there are now a number of substantial oil refineries where practical training can be obtained.

Training and Aptitude

At an early stage the newcomer has to decide, whether he wishes to be connected with a particular phase of specialized engineering activities, or whether he wishes to develop executive abilities in directing the organization and its individuals. This important decision is often not taken soon enough,

and the result is dissatisfaction and failure. As mentioned above his knowledge of the actual work is usually restricted and therefore his judgment cannot be based on the analysis of extraneous factors. All he can do, as a rule, is to analyse his own inclinations with reference to practical application.

As a guide, in this connexion, he should review the major qualifications that are required of the executive and the individual worker, respectively.

The Executive

To be successful as an executive, he must have a personality which is cordial, sociable, and understanding. He must be interested in people, and in addition to his technical qualification, he must have a flair for matters connected with business transactions and financial investigations. Although commercial activities are not, as a rule, executed by the engineer, an understanding of these matters is essential to his functioning as a technical executive. Deep technical knowledge is not a major asset to him, but commonsense and the ability to take a broad view, are important. He must also be capable of taking quick decisions, frequently on an intuitive basis. To make himself a leader in the field, he must be courageous, aggressive to a degree, confident, and enterprising.

The Individual Worker

To be a successful individual worker, a reserved personality is an asset. This man should have an interest in theoretical matters and he must be attracted by technical work itself, even without reference to practical applications. His interest in science and mathematics should be commensurate with the requirements of his trade. In his work he approximates more closely to the artist, than to the craftsman, which implies the possession of a considerable amount of idealism. His reasoning must be methodical and logical. As a rule, he has more time to reach his conclusions than the executive worker, and therefore love for patient research will find a suitable field of application.

Both types of men, realizing that they are members of a large team, should not endeavour to concentrate all activities in their own hands, and thereby produce what is colloquially referred to as "bottlenecks." Unfortunately, this tendency is met with frequently in the petroleum industry, and here again, one reason for an individual being able to persist in his practice, is the large amount of empirical knowledge which is still required. Such empirical knowledge is not infrequently contained in the famous "personal notebook" and is not generally available in the literature or other public sources of reference. Fortunately, the "notebook knowledge" is disappearing in petroleum engineering. The younger generation does not admire the man who works from his notebook, as hoarding of immaterial assets is often indicative of a sign of mental poverty.

Summary of Site Procedure

At the outset a clear appreciation of what has to be done must be formed. This comprises an assessment of the volume of work and the process to be used and of the equipment and machinery which will be utilized.

The Underlying Principle in all Work.

There must be a clear understanding why the project is being executed, and this refers to questions regarding supply and demand of the raw materials to be processed, which, in turn, lead to the general and detailed design work and drawing office work at headquarters. Planning of the work must start at the earliest stage and continue to the end of the construction programme, so that at any intervening period it must be readily evident, what work has been completed and when new phases of

construction activities have to commence.

When this plan is established, then questions arise as to how the work has to be executed. This refers essentially to procurement of the equipment, including buying, inspection, and expediting, as well as transport to site and erection.

Finally, there must be a clear plan as to quantity and quality of manpower to be used, and there must be a time schedule when the various types of workers are introduced into the programme and which individuals are to be employed.

May I conclude this review with the words of a man who, almost certainly, had no ambition to speak authoritatively on engineering procedure but who, nevertheless, in his poetic vision, has summarized the vital elements of successful and creative procedure? The man is Rudyard Kipling and his words are:

I keep six honest serving men,
They taught me all I knew,
Their names are What and Why and When
And How and Where and Who.

★ ★ ★

ECONOMICS AND OPERATIONS GROUP OF THE INSTITUTE OF PETROLEUM

The Council of the Institute recently decided that the pre-war practice of forming groups to discuss particular aspects of the oil industry should be revived and a Group has been formed to cover economics, distribution, storage, and marketing.

The Group held its first meeting in the Institute on 7 October, when a paper on "The International Economic Situation and the World Oil Industry" was followed by lively discussion. The paper will be reproduced in the IP *Review*.

At the express wish of the Council Oliver F. Thompson, O.B.E., a member of the Council, has undertaken to act as Chairman of the Group for the ensuing session and at the first meeting the following members were elected as a committee having the power to co-opt additional members where these may be considered necessary.

The Committee comprises:

A. W. Deller
E. Evans-Jones
G. P. Glass (Honorary Secretary)
M. E. Hubbard
A. L. King
E. C. Masterson
E. Herbert (Secretary)

The next meeting of the Group will be held on 6 January 1954, when M. E. Hubbard of the Anglo-Iranian Oil Co. Ltd. will talk on "The Pattern of Products Demand." As this is a subject that affects so many aspects of the industry it is hoped that this talk will attract a large attendance. A cordial invitation is extended to all those who may be interested. Tea will be provided for a charge of 1/6d.

The new Group will function to give non-technical members of the Institute an opportunity to meet and discuss problems of particular interest in their own fields and will be of interest to many technologists whose work may be influenced by developments outside their own special sphere.

★ ★ ★

100 MILLION TONS OF CRUDE

The Iraq Petroleum Company announce that their Kirkuk Oilfield produced its 100 millionth ton of crude oil in September 1953. Only ten other fields have exceeded this figure in the history of the oil industry. Since 14 October 1927 when well no. 1 at Baba Gurgur came in as a gusher, the field at Kirkuk has been greatly expanded. Today it is considered one of the greatest oil reservoirs in the world.

PROGRESS AT CORYTON

After three years construction, Vacuum Oil Company's 18,000-barrel per day, £12 million refinery approaches completion.

Approximately 95 per cent of the plant has been manufactured in the U.K. and erected by several thousand British workmen, under the direction of American engineers.

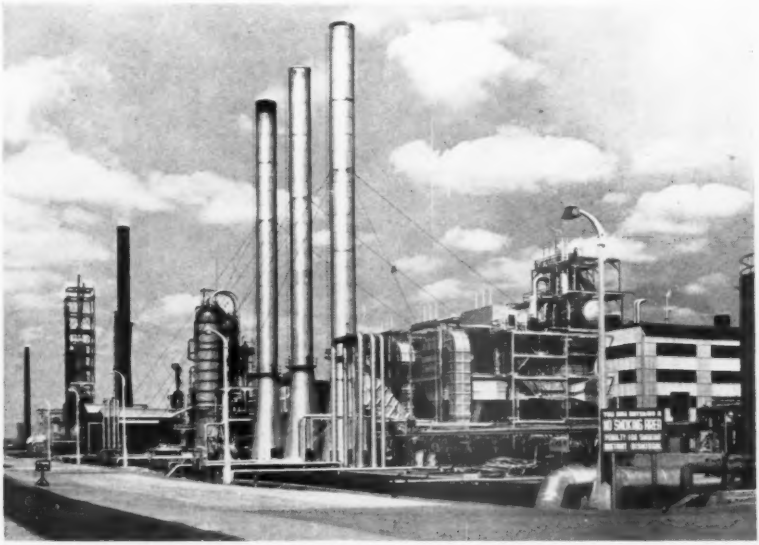
Since January, when the refinery came "on stream" with the starting up of No. 1 boiler, various successive units have been completed, tested, and put into operation. Temporary offices and workshops have been replaced by permanent buildings, a research and testing laboratory has been erected, roads and a railway line have been built, and turf has been laid in front of many of the buildings. There are also an exceptionally fine cafeteria, an extensive locker room fitted with showers, basins, and so on, and a savings bank.

All this has been accomplished in spite of the Spring floods, which inundated the site and caused a 21-day stoppage of production.

Nos. 2 and 3 boilers were started up in April and June, respectively. By the end of June the atmospheric side of the distillation unit, the thermal reformer, the gasoline treating unit, and the ethyl blending unit had been completed. The furfural unit, which removes impurities from the lub oil stocks, and ensures a high viscosity index in the finished products, came into operation at the beginning of August.

The TCC Unit

The 292-ft Thermofor catalytic cracking unit is of particular interest, as this plant, the first of its kind in the U.K., nears completion. It employs the air-lift principle to return the regenerated catalyst to the reaction chamber. Unlike that in the fixed-bed type, the 30 to 50-ton catalyst is moving continuously at an



A. Looking north along "J" Street at Coryton Refinery. T.C.C. unit (l), distillation unit, and power house.

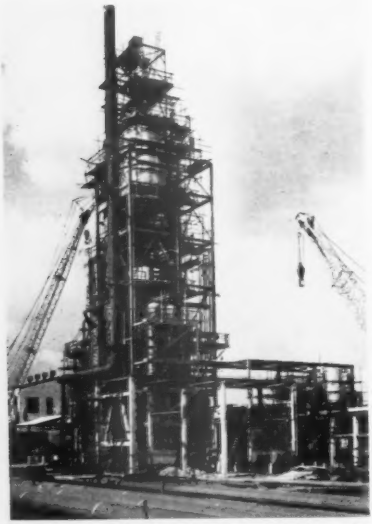
estimated circulation of 280 tons/hr, *i.e.* approximately seven changes per hour.

Also nearing completion are the lubricating oil processing units, which provide stock oils for the company's lubricants, the propane de-asphalting unit, and the methyl ethyl ketone dewaxing unit.

Early in October, the Thermofor continuous percolation unit came into operation. This process uses clay to remove undesirable coloured matter during the final stage in the manufacture of lubricating oil stocks. The plant is the first of its kind in the world.

Refinery Requirements

The refinery draws about one million gallons of fresh water daily from the local mains supply. This is mostly used in the boilers. In addition, over 45 million gallons of water is drawn from the River Thames for cooling purposes. After use this water is filtered and returned to the Thames.



B. The Thermofor continuous percolation unit, looking north-west.

C. The propane de-asphalting unit, looking south-east.

Further technical details of the plant appeared in the October, 1952, issue of this journal, pages 362-4.

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COMMONWEALTH FUND FELLOWSHIP

Twenty fellowships for advanced study and travel in the U.S.A. are being offered to degree graduates (men and women, age 23-32) of a university in the U.K. who have not previously studied in the U.S.A. for more than a few months. The tenure is from 12 to 21 months. Details and application forms are available through British universities or Government Departments or from The Warden, Harkness House, 35 Portman Square, London, W.1. The closing date for applications is 15 December 1953.

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COURSE ON AVIATION FUELS

A short course on aviation fuels will be given at The College of Aeronautics, Cranfield, Bletchley, Bucks., from 23 to 27 November. The course is intended primarily for mechanical engineers and others who wish to obtain an overall knowledge of the subject and its associated applications. Laboratory work and test bed demonstrations will play an important part.

The tuition fee is ten guineas and residence charge (incl. full board) is £6 10s. 0d. Copies of the syllabus and forms of registration may be obtained from the Warden.

WORLD PETROLEUM STATISTICS

World production of crude petroleum in 1952 was 5 per cent greater than in 1951, according to figures* produced by the U.S. Department of the Interior Bureau of Mines. In the four tables reproduced here details are given of crude oil supply and demand, production of major refined products, bunker oil deliveries, and estimated domestic demand for major products for those countries where reasonably complete figures are available. In most instances, demand is refinery production (including refinery fuel consumption) plus imports, minus exports, and plus or minus stock changes. Bunker fuels are included in the demand of the countries where loaded. Table IV is not exactly comparable with that for 1951, since figures for Rhodesia, Nyasaland, Spanish Morocco, Tangier, and Ethiopia were unavailable, whereas those for Angola, Cape Verde Is., Madagascar, and Sudan are included. Details are:

Motor fuel—Includes aviation gasoline, other gasolines and naphthas from crude, and natural gasoline, alcohol, or benzole blended.

Kerosine—Includes all grades of kerosine for power, lighting, and range use.

Distillate fuel oil—Includes gas oil, light diesel oil, and light heating oils.

Residual fuel oil—Includes heavier residuals used for bunkering or fuel under boilers.

Lubricating oil—Includes all grades of lubricating oil and oils used in grease manufacture.

TABLE I
WORLD SUPPLY AND DEMAND—CRUDE PETROLEUM—1952
(Thousands of barrels)

Country	*Production*	*Imports*	*Exports*	*Crude runs to stills*	*Other demand and losses*	*Stock changes*
NORTH AMERICA						
Canada	61,210	82,467	1,116	138,720	300	3,541
Cuba	36	2,861	—	2,898	1	—2
Mexico	78,903	—	9,327	62,323	4,879	2,374
U.S.A.	2,291,997	209,591	26,727	2,441,259	17,457	16,145
Total	2,432,146	294,919	37,170	2,645,200	22,637	22,058
Daily Average	6,645	806	102	7,227	62	60
SOUTH AMERICA AND CARIBBEAN						
Argentina	24,807	24,190	—	46,850	360	1,787
Bolivia	529	—	65	448	5	11
Brazil	750	784	—	1,377	30	127
Chile	906	—	805	88	10	3
Colombia	38,677	—	27,322*	10,784	946	—375
Ecuador	2,839	—	876	1,772	24	167
Neth. Antilles	—	305,935	380	305,118	—	437
Peru	16,403	—	2,339	13,712	159	193
Trinidad	21,258	16,830	1,989	35,108	80	911
Uruguay	—	7,258	—	7,339	—	—81
Venezuela	660,254	—	530,909	125,842	3,300	203
Total	766,423	354,997	564,685	548,438	4,914	3,383
Daily Average	2,094	970	1,543	1,499	13	9
WESTERN EUROPE						
Belgium	—	19,910	22	19,229	—	659
Denmark	—	192	—	176	—	16
France	2,377	156,649	120	157,802	50	1,054
Western Germany	12,435	26,101	—	37,597	141	798
Italy and Trieste	487	73,504	—	72,750	102	1,139
Netherlands	4,975	50,054	117	54,470	60	382
Norway	—	340	—	371	—	—31
Portugal	—	3,577	—	3,564	—	13
Spain	—	6,727	—	6,590	—	137
Sweden	—	8,665	—	8,240	—	425
United Kingdom	407	164,994†	—	164,306	120	975
Total	20,681	510,713	259	525,095	473	5,567
Daily Average	57	1,395	1	1,435	1	15

TABLE I

WORLD SUPPLY AND DEMAND—CRUDE PETROLEUM—1952—(cont.)

(thousands of barrels)

Country	*Production*	*Imports*	*Exports*	*Crude runs to stills*	*Other demand and losses*	*Stock changes*
MIDDLE EAST						
Bahrein Island	11,004	59,176	—	69,980	118	82
Egypt	16,464	725	—	17,374	115	—300
Iraq	140,799	—	129,072	4,990	1,640	5,097
Israel	—	6,600	—	6,086	—	514
Kuwait	273,433	—	264,027	9,426	204	—224
Lebanon	—	4,075	—	4,075	—	—
Persia	10,100[e]	—	—	10,000[e]	100[e]	—
Qatar	25,254	—	24,837	—	125[e]	292
Saudi Arabia	301,861	—	237,323	62,204	575	1,759
Turkey	146	—	—	85	61	—
Total	779,061	70,576	655,259	184,220	2,938	7,220
Daily Average	2,129	193	1,790	503	8	21
OTHER ASIA						
China	730[e]	—	—	700[e]	30[e]	—
Formosa	18	2,010	—	1,887	—	141
India-Burma and Pakistan	4,129	—	—	4,035	41	53
Japan	2,100	28,768	—	30,808	48	12
Total	6,977	30,778	—	37,430	119	206
Daily Average	19	84	—	102	—	1
OTHER AFRICA						
Algeria	357	—	265	—	92	—
Canary Islands	—	7,582	—	7,131	—	451
French Morocco	749	—	—	741	15	—7
Total	1,106	7,582	265	7,872	107	444
Daily Average	3	21	1	22	—	1
OCEANIA						
Australia	—	6,967	—	7,120	—	—153
British Borneo	38,251		13,990	85,822	1,060	1,599
Indonesia‡	64,220					
New Zealand	2[e]	—	—	—	2	—
Total	102,473	6,967	13,990	92,942	1,062	1,446
Daily Average	280	19	38	254	3	4
TOTAL ABOVE COUNTRIES	4,108,867	1,276,532	1,271,628	4,041,197	32,250	40,324
Daily Average	11,226	3,488	3,474	11 042	88	110
USSR AND EASTERN EUROPE						
USSR§	329,400[e]	—	—	319,400[e]	10,000[e]	—
Other Eastern Europe	61,500[e]	2,400[e]	—	62,700[e]	1,200[e]	—
Total	390,900	2,400	—	382,100	11,200	—
Daily Average	1,068	7	—	1,044	31	—
WORLD TOTAL	4,499,767	1,278,932	1,271,628	4,423,297	43,450	40,324
Daily Average	12,295	3,494	3,474	12,086	119	110

*Excludes reduced crude (4,706,000 barrels) delivered to pipeline and mixed with crude exported.
†Excludes reduced crude from Netherlands Antilles.
‡Includes New Guinea production, 1,725,000 barrels.
§Includes Sakhalin.
Partly estimated.
[e] Estimated.

**World Petroleum Statistics*, 1952, prepared by J. V. Hightower, under the direction of H. J. Barton. U.S. Bur. Mines WPS No. 52.

TABLE II

PRODUCTION OF MAJOR REFINED PRODUCTS BY COUNTRIES—1952*
(thousands of barrels)

Country	Motor fuel	Kerosine	Distillate fuel oil	Residual fuel oil	Lubricating oil	Total Major products
NORTH AMERICA						
Canada	59,953	7,631	25,292	32,781	1,689	127,346
Cuba	846	633	684	378	13	2,554
Mexico	15,091	6,279	5,859	32,074	250	59,553
U.S.A.	1,189,781	132,300	521,264	454,784	55,600	2,353,729
SOUTH AMERICA AND CARIBBEAN						
Argentina	13,120	5,795	6,390	16,715	680	42,700
Bolivia	249	74	48	69	—	440
Brazil	474	85	231	432	4	1,226
Colombia	2,299	521	648	7,750†	68	11,286
Chile	27	5	23	28	—	83
Ecuador	584	143	295	736	—	1,758
Neth. Antilles	47,879	19,627	36,755	198,245	1,418	303,924
Peru	5,328	1,623	1,593	5,870	81	14,495
Trinidad	7,260	4,588	5,475	17,273	3	34,599
Uruguay	1,684	968	949	3,584	—	7,185
Venezuela	19,666	4,319	26,635	70,918	777	122,315
WESTERN EUROPE						
Belgium	4,535	542	2,852	9,975	51	17,955
Denmark	—	—	37	9	—	46
France	39,462	4,229	26,523	73,178	2,433	145,825
Western Germany	14,697	388	10,631	5,621	2,506	33,843
Italy and Trieste	15,185	4,760	13,465	31,821	459	65,690
Netherlands	16,911	1,580	11,815	19,691	450	50,447
Norway	65	—	69	49	59	242
Portugal	740	527	850	1,352	—	3,469
Spain	1,725	147	1,659	2,794	—	6,325
Sweden	1,339	479	1,279	4,293	116	7,506
United Kingdom	40,622	7,183	29,156	73,437	2,587	152,985
MIDDLE EAST						
Bahrein Island	19,171	8,868	9,730	27,271	—	65,040
Egypt	1,588	1,703	898	12,124	—	16,313
Iraq	780	830	430	2,790	—	4,830
Israel	1,235	876	895	2,745	—	5,751
Kuwait	178	67	1,907	7,002	—	9,154
Lebanon	1,009	503	731	1,762	—	4,005
Persia	2,300‖	1,550‖	1,310‖	4,420‖	—	9,580
Saudi Arabia	12,265	4,996	16,030	27,618	—	60,909
Turkey	8	—	30‖	—	—	38
OTHER ASIA						
China	240‖	60‖	60‖	300‖	—	660
Formosa	505	253	294	705	20	1,777
India-Burma and Pakistan	1,015	590‖	660‖	1,555	110	3,930
Japan	9,010	702	6,300	11,022	1,463	28,497
OTHER AFRICA						
Canary Islands	1,418	383	2,049	2,538	50	6,438
French Morocco	119	62	238	300	—	719
OCEANIA						
Australia	2,718	8	1,005	2,541	177	6,449
Indonesia and British Borneo	22,140	8,342	24,803	23,019	—	78,304
TOTAL ABOVE COUNTRIES	1,575,221	234,219	797,847	1,191,569	71,064	3,869,920
Daily Average	4,304	640	2,180	3,256	194	10,574

*From crude petroleum, natural gasoline blended and oils rerun.
†Includes reduced crude.
‖Estimated.
Partly estimated.

TABLE III
BUNKER OIL DELIVERIES TO VESSELS ENGAGED IN INTERNATIONAL TRADE—1952†
(thousands of barrels daily)

Zone	*Gas, diesel, and other oils*	*Fuel oil*	*Total*
U.S.A. (Continental)	28·0	178·2	206·2
Canada	1·8*	14·0*	15·8*
Central and South America	10·1	34·3	44·4
West Indies	29·6	102·1	131·7
West Africa	9·4	19·4	28·8
U.K. and Irish Republic	19·2	44·6	63·8
N. Europe (Including French and Atlantic ports)	24·6	49·5	74·1
Mediterranean (Including Spain and Portugal)	19·4	45·9	65·3
Middle East (Including Egypt, Red Sea, and Persian Gulf)	26·8	80·6	107·4
South and East Africa	3·8	13·0	16·8
India, Burma, and Ceylon	1·6	13·0	14·6
East and South Asia (Including Indonesia and Japan)	16·9	42·3	59·2
Australasia	4·5	13·9	18·4
TOTALS	195·7	650·8	846·5
Total excluding U.S.A.	167·7	472·6	640·3

†Bunkers from British companies lifted in a country's overseas possessions may not be precisely allocated.
*Estimate—Canadian figures not available.

TABLE IV
ESTIMATED DOMESTIC DEMAND FOR MAJOR PRODUCTS—1952
(thousands of barrels)

Country	*Motor fuel*	*Kerosine*	*Distillate fuel oil*	*Residual fuel oil*	*Lubricating oil*	*Total major products*
NORTH AMERICA AND CARIBBEAN						
Alaska and Hawaii	4,707	167	3,309	6,054	123	14,360
Canada	65,660	10,100	32,231	38,603	2,650	149,244
Central America	2,590	430	2,740	6,180	100	12,040
Cuba	4,650	664	1,612	9,811	210	16,947
Mexico	17,874	6,196	5,910	29,206	575	59,761
Puerto Rico	2,572	685	292	3,002	57	6,608
U.S.A.	1,154,254	124,583	479,764	555,863	38,150	2,352,614
Other W. Indies	2,900	400	10,900	30,400	190	44,790
SOUTH AMERICA						
Argentina	13,500	6,200	6,900	34,500	1,210	62,310
Bolivia	495	92	210	435	9	1,241
Brazil	20,397	2,718	6,285	14,900	1,069	45,369
Chile	2,725	617	1,000	5,008	158	9,508
Colombia	4,440	801	986	3,095	161	9,483
Ecuador	709	143	295	736	25	1,908
Peru	3,617	1,332	1,131	4,275	117	10,472
Uruguay	1,793	982	1,120	4,120	68	8,083
Venezuela	7,905	2,297	5,310	13,660	329	29,501
Other	195	65	45	5	20	330
WESTERN EUROPE						
Belgium and Lux.	7,685	616	4,593	6,889	586	20,369
Denmark	4,185	625	2,737	4,778	262	12,587
Finland	2,265	475	1,090	959	150	4,939
France	29,150	995	16,340	46,700	2,675	95,860
Germany, Western	14,264	390	15,450	8,248	2,492	40,844
Greece	2,150	720	2,050	3,750	115	8,785
Iceland	430	30	725	475	25	1,685
Ireland	2,590	827	619	1,761	110	5,907
Italy and Trieste	8,750	1,885	8,775	28,310	945	48,665
Netherlands	5,710	2,250	8,690	14,720	520	31,890
Norway	2,459	390	5,307	5,530	229	13,915
Portugal	1,445	999	1,830	2,865	130	7,269
Spain	4,795	245	2,720	4,450	350	12,560
Sweden	7,564	2,140	12,982	12,327	520	35,533
Switzerland	3,281	530	4,770	530	250	9,361
United Kingdom	53,381	15,186	28,562	52,320	5,350	154,799
MIDDLE EAST						
Bahrein Island	95	63	1,328	7,088	13	8,587
Iraq	810	890	510	2,750	120	5,080
Israel	1,350	1,070	910	3,120	100	6,550
Jordan	240	175	98	—	6	519
Kuwait	179	64	133	6,318	2	6,696
Saudi Arabia	935	130	2,645	9,009	25	12,744
Syria-Lebanon	1,566	568	1,212	1,620	63	5,029
Turkey	2,675	1,570	1,500	350	275	6,370

TABLE IV
ESTIMATED DOMESTIC DEMAND FOR MAJOR PRODUCTS—1952—(cont.)
(thousands of barrels)

Country	*Motor fuel*	*Kerosine*	*Distillate fuel oil*	*Residual fuel oil*	*Lubricating oil*	*Total Major products*
OTHER ASIA						
Burma	710	290	220	230	50	1,500
Ceylon	1,051	538	1,175	3,668	60	6,492
India	8,095	8,670	4,960	5,775	1,345	28,845
Indo-China	1,081	332	350	282	84	2,129
Japan	9,850	675	2,495	19,750	2,390	35,160
Malaya	2,525	685	5,875	9,860	170	19,115
Pakistan	1,490	1,423	1,265	4,620	210	9,008
Thailand	1,286	493	858	—	89	2,726
AFRICA						
Algeria	1,970	457	1,085	5,273	134	8,919
Angola	275	35	75	55	23	463
Cape Verde Island	24	3	395	1,928	1	2,351
Egypt	2,450	5,295	4,316*	17,802*	342	30,205
Madagascar	348	72	128	1	45	594
Morocco, French	2,250	325	975	1,740	120	5,410
Sudan	450	130	280	575	50	1,485
Tunisia	700	265	650	600	62	2,277
Un. So. Africa	10,170†	3,270	2,980	2,700	600	19,720
OCEANIA						
Australia	21,798	3,591	9,750	7,960	1,487	44,586
Indonesia	3,690	2,950	3,280	4,360	190	14,470
New Zealand	5,310	225	1,400	2,640	250	9,825
Philippine Islands	4,150	1,195	2,550	2,415	250	10,560
TOTAL ABOVE COUNTRIES	1,548,610	222,224	730,678	1,076,954	68,486	3,646,952
Daily Average	4,231	607	1,996	2,942	187	9,963

*Includes transit trade in ship bunkers.
†Includes South West Africa.

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CHEMICAL ENGINEERING

Part IV—Transfer of Heat

By D. C. FRESHWATER

In the petroleum industry almost all the important refinery processes involve the transfer of heat, as for example in distillation of the crude or in cracking, and in condensation of vapours or dewaxing of lubricating oils. In distillation, which is the largest single unit operation used in the industry, part of the crude oil is flash vaporized by heating in a pipe still, then vapour and liquid are separated and fractionated in a tower; the products being taken off as liquids and vapours. Liquid products must be cooled and vapours condensed and cooled. Heat is supplied to the charging stock and removed from the refined products, and the fractionating column can be considered as approximating to an adiabatic apparatus in which heat is supplied at the base of the tower and abstracted at the top.

This supply and removal of heat must be carefully controlled in order to obtain the most economical operation from a thermal viewpoint, and the heaters and coolers used must be adequate for the duty required. It is, therefore, essential to understand the laws governing heat transfer in order to design suitable equipment.

General Principles

Heat flow may occur by three methods: conduction, convection, and radiation, each of which may occur separately or in any combination in many different types of plant.

The transfer of heat is of such pro-

found importance in industrial operations that it has been studied very extensively and complete theoretical treatments have been developed for those cases which have proved susceptible to mathematical analysis. Many systems of heat transfer of industrial importance can, however, only be solved by analogy with much simpler systems, as at present no exact solutions of many such systems used in practice are known.

Conduction

Heat transfer by conduction takes place when there is a difference in temperature between points on the same body, or when two different bodies at different temperatures are in contact.

The flow of heat does not depend upon a flow of material as in convection heating. The heat is transferred from one particle of matter to the next simply by contact between them. Conduction is usually associated with the other mechanisms in practice but in the equipment involving the use of heat insulating and refractory materials it is of prime importance, radiation and convection effects playing little or no part in the flow of heat through such systems.

This is the simplest mechanism in which the rate of heat flow is directly proportional to the driving force per unit area divided by the resistance, or:

$$Q = KA\,(dt/dL)$$

where Q is the heat transferred per unit time, A is the area normal to the direction of flow, dt is the temperature difference at the extremes of the infinitesimal length, dL, K is the proportionality constant, and is termed the thermal conductivity. It is a measure of the ease with which a substance transmits heat.

The equations usually quoted in handbooks for the flow of heat through plane walls or pipes are derived from the above equation by integration, assuming that K does not vary with temperature.

It should be noted that flow of heat is analogous to flow of electricity where one talks of resistance rather than conductance. Resistance is the reciprocal of conductance, *i.e.* for heat flow $1/K$ is the thermal resistance, and where heat flows through layers of different materials the reciprocal of the total resistance is equal to the sum of the reciprocals of the individual resistances.

Convection

Heat transfer by convection takes place by the movement of heated particles of matter through the main body of the material being heated and is therefore confined to fluids. For ease of handling and control, as explained in the article on fluid flow, materials are preferentially processed in the liquid or gaseous state and therefore convection is most important in practice. In the heating or cooling of fluids, transfer of heat by conductance takes place through the walls of the retaining vessel. Heat moves through the body of the fluid by convection, which may be natural, due to temperature differences within the fluid, or forced, due to mechanically induced turbulence in the fluid.

Film Concept

Before mathematical solutions can be developed it is necessary to make two assumptions. The first is that there is a film of fluid next to the metal wall which is stagnant. Experimental evidence shows that this is so. The second assumption is that with such a film the flow of heat is analogous to fluid flow. This film is stagnant and heat flows through it only by conduction but since the film thickness dL is not known and cannot be measured accurately the rate equation is written as:

$$Q = h_f\, A \Delta t$$

where A = interfacial area, Δt = temperature difference between retaining wall surface and bulk of fluid, h_f = film coefficient of heat transfer.

Actually $1/h_f = dL/K_f$ for the film, plus

the small thermal resistance R_f of the fluid outside the film or $1/h_f = (dL/K_f) + R_f$.

Since it is practically impossible to measure dL, heat transfer through films is always expressed in terms of h_f.

The problem then is to find K, for a given set of conditions. The second assumption (that the flow of heat is analogous to fluid flow) leads to the conclusion that h_f varies with the Reynolds number of the fluid. h_f will also vary with the specific heat C_p, and the thermal conductivity of the material. For turbulent flow through pipes of circular cross-section, dimensional analysis shows that three dimensionless ratios are involved. These are the Reynolds number Dup/μ, the Prandtl number $Cp\mu/K$ and the Nussets number hD/k.

where μ is the fluid viscosity, C is the specific heat, k is the thermal conductivity, all in terms of self-consistent units.

From a large number of experimental observations, it is found that the expression

$$hD/k \,.(\epsilon_p \mu)^{n-1}/k = 0{\cdot}023 \;(Re)^{0{\cdot}8}$$

where $n = 0{\cdot}6$ if the fluid is being heated and $0{\cdot}7$ if it is being cooled.

The heating and cooling of fluids flowing inside pipes has been studied far more extensively than other types of fluid-solid contact and for flow outside tubes, correlations given so far are only tentative.

One of the most important conclusions that follow from the above analysis is that the thinner the film, the greater the rate of heat transfer. Hence, under turbulent flow conditions as high a Reynolds number as is compatible with pressure drop considerations is desirable.

Overall Coefficients and Logarithmic Mean Temperature Differences

In heat exchangers, the heat flows from one fluid to another through a metal retaining wall and there are two films, one on each side of the wall, and also the resistance of the wall itself to be considered. Often these three resistances are combined for convenience in calculations and the reciprocal of their sum is termed the overall coefficient of heat transfer, Uo, *i.e.*

$$Uo = \frac{1}{\frac{1}{hf} + \frac{L}{K} + \frac{1}{hf_2}}$$

and is expressed as quantity of heat/(unit time) (unit area) (unit temp. difference). Many values of U for practical cases are quoted in the reference books. Assuming the thermal conductivity, specific heat, and viscosity of each fluid remains reasonably constant then U will be constant in a given piece of heat exchange equipment. The problem then resolves itself into allowing for variation in temperature differences from point to point in the equipment using the basic differential equation

$$dq = U\Delta t \; dA$$

For the simple case where the change in Δt is proportional to the heat transferred, this equation can be integrated to give:

$$q = U\, A \Delta t_m,$$

$$\text{where } t_m = \frac{t_2 - t_1}{log\, e\, \frac{t_2}{t_1}},$$

and is called the logarithmic mean temperature difference.

t_2 = the temperature difference between the two fluids at one end of the apparatus,

t_1 = the temperature difference between the two fluids at the other end of the apparatus.

Relations have been worked out for the various types of multipass heat exchangers which are discussed later, enabling the ratio between the true mean temperature difference and t_m to be found.

Condensation of Vapours and Boiling Liquids

So far heat transfer without change of state only has been considered. When a vapour condenses on a cool surface a film of liquid is formed. Further condensation can only take place on this film and therefore the process is limited to the rate at which heat can be transferred through this film to the cool surface. Since most liquids are poor conductors of heat this film offers the major resistance.

However, sometimes, as for example when steam condenses on a greasy metal tube, the cool surface is not "wetted" and surface tension causes the condensate to form into isolated drops which may fall off a vertical surface. A large fraction of the cooling surface may be left bare and would be available for further condensation. These two mechanisms are known as film and dropwise condensation, respectively.

Several expressions have been developed to allow coefficients for film type condensation to be calculated. These show that normally a horizontal heat exchange is more effective than a vertical one.

When dropwise condensation occurs, *e.g.* condensing steam containing slight traces of an additive such as benzyl mercaptan, coefficients two or three times as great as those obtainable with film-type condensation are found.

It has not proved possible to calculate with any degree of accuracy the film coefficients to be expected with boiling liquids inside or outside tubes, and it is usual to design such equipment on the basis of overall coefficients obtained experimentally with a heat exchanger similar to the one it is proposed to use.

Scale Coefficients

Deposits or scale gradually form on the metal walls of the heat exchangers. Such scales have rather poor thermal conductivities and hence the performance of a heat exchanger will deteriorate when in service as these deposits form.

To ensure that the exchanger is of adequate size, some allowance must be made for the extra resistance of the scale, but since it is difficult to predict its thickness it is usual to consider it as an extra film to which arbitrary values are given, based on experience and depending upon the type of service.

Scale factors h_s (which $= \frac{Ks}{Ls}$) suggested by one authority are as follows:

	B.T.U/hr/sq.ft/ F.
For condensing steam . .	3000
For condensing petroleum vapours	500
For heating clean water .	3000
For heating muddy water .	600
For heating topped crude or petroleum residue . .	200

Radiation

Radiation is the emission of energy by electro-magnetic wave motion. It takes place from all surfaces, requires no intervening medium for its transmission and is a function of the temperature and state of the surface.

Thus a hot body gives out more than a cold one and if the radiation from the hot body falls on the cold body some of it will be absorbed and converted quantitatively into heat.

The mechanism of heat flow by radiation is quite as complex as the convection process, since heat transferred is proportional to the fourth power of the temperature difference between the radiating and absorbing surfaces. The physical character of the surfaces also affects the rate at which heat may be radiated or absorbed. Some types of surfaces have a much greater power of radiating than others, the best radiators (and conversely absorbers) being those with a perfectly black matt or non-reflecting surface and the worst being highly polished or silvered surfaces. The surface factors or emissivities of many materials encountered industrially have been

experimentally determined and may be found in tables or physical constants. The equation for the general case of radiation based on the Stefan-Boltzmann laws may be expressed as:

$$Q = 0{\cdot}173\, e_1 e_2 \left\{ \left\{ \frac{T_1}{100} \right\}^4 - \left\{ \frac{T_2}{100} \right\}^4 \right\}$$

where Q is the heat transferred in B.T.U/sq.ft/hr., e_1 is the emissivity of the hot surface, e_2 is the emissivity of the cold surface, T_1 is the temperature of the hot surface in °F absolute, T_2 is the temperature of the cold surface in °F absolute.

In radiation calculations the effective heating surface of the radiating body is the area "visible" to the heat receiving body. This is usually determined by measuring the solid angle subtended by the hot body but the correction factors are rather complex and beyond the scope of this discussion.

It is evident from the equation given above that heat transfer by radiation becomes more important in processes operating at high temperatures, such as pipe stills or cracking plants.

In the case of furnaces where large volumes of hot gases are encountered, an appreciable part of the heat transferred is radiated direct from the hot gases. Among the more usual gases only CO_2 and water vapour are effective radiators, and for these many data for different temperatures and conditions of service are available. Yellow flames have a higher radiating power than non-luminous flames, and if the hot gas contains solid particles it may become luminous and the radiation from it is then greatly increased.

Heat exchangers

The vast majority of heat exchangers with which the chemical engineer is concerned are those where heat passes from one fluid to another through a tubular retaining wall, usually of metal. In the pipe still, radiation plays a large part but even here convection is important in the "convection section," where the oil inside the tubes is heated by hot combustion gases outside the tubes. Only equipment in which the heat exchange is between two fluids is considered here. Such equipment may be divided into three types of construction, each of which is described in order of importance.

Shell Tube Exchangers

As the name implies, these consist of a number of parallel tubes held at each end by a tube plate and connected to a common inlet and outlet (known as the headers) through which one of the fluids is passed. The second fluid passes outside the tube and is confined by means of a cylindrical shell which completely encloses the tube bundle (Fig 1).

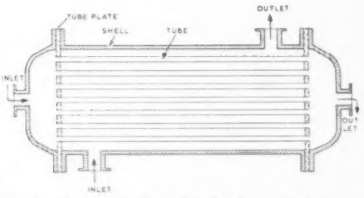

Fig 1. Simple shell and tube heat exchanger.

From the earlier discussion it is clear that highly turbulent flow inside the tubes is desirable. However, tubes are normally obtainable in standard lengths of 8 or 14 ft and the heat transfer area, *i.e.* tube area, is fixed by the heat requirements of the exchanger, and hence the number of tubes of a given diameter is also fixed. If all the fluid passes through the tubes simultaneously as in Fig 1, it may be found that the velocity in the tubes is not in the turbulent region. This is easily overcome by dividing the headers into a number of compartments so that the fluid passes successively through groups of tubes backwards and forwards through the exchangers (Fig 2). This converts a

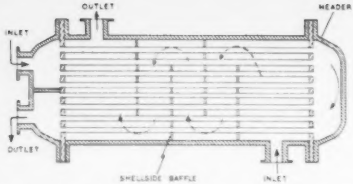

Fig 2. Double pass shell and tube heat exchanger.

single-pass heat exchanger to a multi-pass exchanger.

The performance of a heat exchanger may be improved by fitting baffles outside the tubes so that the velocity of the fluid on the shell side is increased.

The double pass exchanger with baffles on the shell side (Fig 2) is used for high heat transfer duties, and may be fabricated in a wide variety of metals, such as mild steel, stainless steel, copper, nickel, and aluminium.

Concentric Tube Exchangers

In these exchangers the shell encloses a single tube. Clearly, very little heat exchange surface is obtainable with such an apparatus when using a single 8-foot standard tube, and hence such an exchanger in practice comprises a number of concentric tube assemblies connected together in series (Fig 3). Concentric tube or jacketed pipe exchangers are used for small duties of up to, say, 1000 g.p.h., and are particularly useful where corrosive fluids have to be handled as their method of construction makes it possible to use materials, such as glass or carbon, for the inner tube.

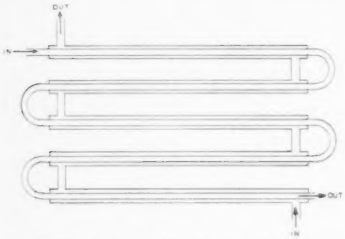

Fig 3. Jacketed pipe heat exchanger.

Coil-in-bath Type Exchangers

These heat exchangers (Fig 4) represent the earliest form of condensers as used by the alchemists. They comprise a coil immersed in a tank. They are simple and cheap to construct but are inefficient and for all except the smallest duties expensive in materials. They find a specialized application when handling very corrosive liquids since they can be fabricated with both tank and coil in corrosion resisting materials, such as chemical stoneware or glass.

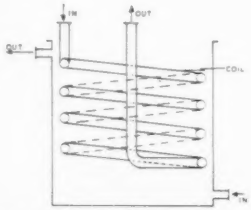

Fig 4. Coil-in-bath heat exchanger.

Heat Exchanger Duties

In the above consideration, heat exchangers are classified according to their mechanical construction. However, another equally valid classification of such equipment may be based on the type of duty performed by the exchanger, and the nature and states of the fluids being handled. These are as follows:

(*A*) *Heat exchange without change of state of either fluid.*
- (1) Liquid-liquid exchangers,
- (2) Gas-gas exchangers,
- (3) Liquid-gas exchangers.

(*B*) *Heat exchange with change of state of one fluid.*
- (1) Condensing vapour-gas,
- (2) Boiling liquid-liquid,
- (3) Condensing vapour-liquid,
- (4) Boiling liquid-gas.

(C) Heat exchange with change of state of both fluids

Condensing gas-boiling liquid.

However, in practice this rather theoretical classification gives way to a nomenclature built up by long usage and tradition rather than logic.

The justification for this lies in the fact that some classes of exchangers are very widely used compared with others, and such types have been given names more descriptive of the job they do.

Some examples of commoner types follow, together with brief notes on how the heat transfer conditions influence the construction of the equipment:

Feed Preheaters. These are usually liquid-liquid heat exchangers in which the cold feed to a process is preheated by using one of the hot liquid products leaving the process. This is a relatively straightforward problem, but it is important to ensure turbulent flow on both sides of the heat exchanger surface. The cold feed which is heated often contains dissolved gases, which are released as the temperature of the liquid rises. Such gases may accumulate inside a multiple-pass exchanger and seriously reduce its performance by blanketing off some of the heat exchange surface. Such feed preheaters therefore must be designed so that gases liberated can be removed by adequate venting arrangements.

Air or Gas Preheater. Where hot air or gas is required, as for example in drying, a common method of heating the air is to pass it over tubes heated internally by steam. The steam in condensing gives up its heat to the main body of the air, through a film of condensate, the metal wall, and a film condensate, the metal wall and a film of air.

Of these three resistances to the flow of heat that of the gas film is so large relatively to the others that it virtually controls the rate of heat transfer in the equipment; thus common practical values for film coefficients in B.T.U/(hr)(sq.ft.)(°F) are of the order of 1000 for condensing steam and 10 for a gas being heated. Since ordinary tubular equipment based on these heat transfer rates would be greatly oversize on the steam side, the external tube area is artificially increased by the addition of metal fins to the outside of the tubes. These fins may be longitudinal strips, closely spaced annular disks concentric with the tubes, or in the form of helical strips wound round the tube, and by such means the external metal surface in contact with the air may be trebled. The increased metal resistance is negligible because of the high thermal conductivities of metals.

The fins serve another useful purpose in that they increase the turbulence of the gas flowing over them, and thus reduce the thickness of the gas film; as the power consumed in overcoming friction is increased at high velocities and erosion of tube surfaces may take place, so there is a limit to the reduction of the gas film resistance which may be achieved by high turbulence.

Finned tubes are widely used wherever heat transfer between gases and liquids or vapour is to be performed, and occasionally for gas-gas heat exchange. Common examples of such application are boiler economizers, combustion air preheaters and air-cooled internal combustion engines.

Condensers

Although condensation takes place in many types of heat exchanger, *e.g.* in nearly all steam heated equipment, the name condenser is used only where such a heat exchange is embodied in the lower temperature or heat rejection part of a process as, for example, in the heat exchanger at the end of a steam power cycle. The commonest example in the petroleum industry is the exchanger used to condense the vapours from the top of a distillation column.

In such equipment the cooling medium is usually water or less often a cold process liquid which it is desired to heat. This consideration is here confined to such systems, *i.e.* those grouped under B3 above. Occasionally, when the vapours to be condensed are at a high temperature, the cooling medium may be boiling water (so-called evaporative condensers) or air, the latter being used despite its lower efficiency where supplies of water are very limited. In the usual water-cooled condenser, film type condensation occurs in the majority of cases, and from what has been said earlier, it is theoretically desirable that such exchangers should be installed with the tubes horizontal, but practical consideration such as available floor space often dictates that condensers be installed in a vertical position. In practice condensers are installed on a slight slope to allow the condensate to drain to the end from which it is removed.

Overall heat transfer coefficients of the order of 200 to 300 are usually obtained with such equipment, the limiting factor usually being the film coefficient on the water side which seldom exceeds 50 to 60 B.T.U/hr (sq.ft.) F. Thus turbulent flow is essential on the water side and hence all but the smallest condensers are multipass. Since cooling water taken from rivers or estuaries is often "dirty" provision for cleaning the surfaces in contact with the water is important. This can best be done by passing the water inside the tubes as the inside of the tubes can be cleaned very much easier than the outside.

The high specific volume of most vapours leads to a high vapour velocity on the shell side. Often this makes baffling on the shell side unnecessary. Where baffling is used, however, adequate provision must be made for the condensate to pass between the edge of the baffle and the shell to prevent liquid building up and blanketing the heat transfer surfaces. The vapour velocity is highest at the inlet to the condenser and it is common to find a special impingement plate fitted inside the shell to take the first force of the vapours entering and prevent erosion of the tubes near the inlet.

Reboilers

There are heat exchangers in which a process material is vaporized by a hot medium, usually steam, but occasionally, in special cases where temperatures in excess of 400 F are required, a liquid such as Dowtherm. The most common application of such exchangers is for the provision of heat at the bottom of a distillation column. These heaters are invariably constructed with the process fluid inside and the heating medium outside the tubes. This is partly for ease of cleaning, since the process fluid is far more likely to cause scale to deposit when heated than is condensing steam, and partly to increase the rate of heat transfer.

As the liquid boils inside the tubes, pockets of vapour are generated. These pockets cause rapid expansion and owing to the confined space inside the tube this expansion drives slugs of liquid rapidly out of the tube. Where the heater is placed vertically with the tube plates below the level of the liquid inside the column, the displaced liquid is replaced by fresh non-boiling material from inside the column by normal gravity flow. This process maintains itself continuously and a very high rate of circulation may thus be achieved.

It has been found in practice that good results are obtained when the heater is located so that the static liquid level inside the column is sufficient to cause two-third submergence in the tubes. In these conditions circulation rates of three to four times that calculated by simple displacement of the vapour generated have been measured by overall coefficients of the order of 300 to 500 B.T.U/hr(sq.ft.) F have been

found. This arrangement is essentially single pass and is difficult to accomodate to very large duties.

For larger duties, forced circulation is used employing a low head, high capacity pump of the axial flow type to transfer liquid from the column to the heater. Special care must be exercised in the choice of materials of construction for reboiler since the tubes may be subjected to severe erosion conditions owing to the high liquid velocity through them.

This article has dealt only with the main characteristics of a few of the more important types of heat exchanger; for further reading see:

Process Heat Transfer. D. W. Kern. McGraw-Hill Publ. Co.

Heat Transfer. Fisher and Saunders. Oxford U.P. (1950).

Applied Heat Transmission. Stower. McGraw-Hill Publ. Co. (1941).

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PROFESSOR L. UBBELOHDE

Professor L. Ubbelohde

On 4 January 1950 Professor L. Ubbelohde, Hon.F.Inst. Pet., attained his 75th year and in celebration thereof and as a tribute to his services to science and industry, a commemorative volume* has recently appeared. Among those who have paid tribute to Professor Ubbelohde the personal messages which form the first part of the book are Col. S. J. M. Auld, Dr G. Egloff, and Professor F. H. Garner.

The bulk of the book is devoted to accounts of the work which Professor Ubbelohde has carried out in his varied spheres of interest. Each account is written by someone associated with him in that particular work or by someone well acquainted with his achievements. There are a number of interesting photographs of Professor Ubbelohde and his colleagues, including an excellent reproduction of the group taken on the occasion of the first World Petroleum Congress in London in 1933.

*Leo Ubbelohde. Pp. 156 + viii. Karlsruhe, Verlag C. Braun, 1952. Dm. 12.

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PERSONAL NOTES

Dr Wilburn C. Schroeder has recently resigned as assistant director for programming of the U.S. Bureau of Mines to teach chemistry and chemical engineering at the University of Maryland and to engage in private consulting practice. Dr Schroeder is particularly known in the petroleum industry for his work on the production of gasoline and other liquid fuels from coal and oil shale.

George Powell was recently presented with a diamond-pointed gold star to mark the completion of 30 years' service with the Esso Petroleum Co. Until a few years ago Mr Powell was manager of the Company's Bristol office, controlling operations throughout South Wales and the South-western counties, an appointment which he held for 15 years until his promotion to a senior position at Head Office.

George Powell (l) and Leonard Sinclair (chairman and managing director of Esso Petroleum)

J. E. Cook has been appointed regional manager of Fina Petroleum Products at Gunnes, Lincolnshire. Mr Cook joined the Fina organization in February 1952 as deputy manager of the South Eastern Region (then London division).

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Drilling in Sicily. D'Arcy Exploration Company have begun drilling their first test well near Vittoria, in Southern Sicily.

IP/ASTM CO-OPERATION IN STANDARDIZATION

Co-operation between IP and the American Society of Testing Materials in the sphere of the testing of petroleum and its products advanced considerably during September. During that month Dr Fred D. Tuemmler, chairman of the Co-ordinating Division on Test Methods of ASTM Committee D-2 on Petroleum Products and Lubricants spent the best part of a fortnight discussing many and varied topics of mutual interest to both bodies.

During his visit Dr Tuemmler met members of IP Standardization Committee and its various sub-committees and panels collectively and individually and the subjects discussed were wide in scope and aspect.

Dr Tuemmler returned to the U.S.A. on 25 September to report to Advisory Committee of D-2 and it is anticipated that his visit and discussions will result in a still greater degree of agreement between both organizations.

Shortly prior to his return home Dr Tuemmler was entertained at lunch by members of IP Standardization Committee, the chair being taken by H. S. Gibson, C.B.E., the president of the Institute.

Proposing Dr Tuemmler's health, the chairman welcomed him as a protagonist in IP/ASTM co-operation in the field of standardization of petroleum testing. He was also glad that Dr Tuemmler had been able to spend so much time with IP representatives in discussion of standardization matters and was sure that only good would result from these discussions. He asked Dr Tuemmler to convey to his colleagues in the U.S.A., the greetings of their friends in the IP.

Dr F. D. Tuemmler with (r) H. S. Gibson, C.B.E. President of the IP.

Mr H. Hyams, chairman of ASTM/IP Co-ordination Committee, in seconding the toast, paid tribute to Dr Tuemmler's happy and congenial character, typified by his charm and his invariably expansive smile. During the two weeks of his stay Fred Tuemmler had been kept hard at work, frequently well into the evening. Everyone had been impressed by his complete grasp of the detail of literally hundreds of test methods, and the practical significance of the results obtained with such methods.

The benefits to be derived from the unification of ASTM and IP methods were, Mr Hyams said, very considerable. Full co-operation by both sides was essential to success, and Fred Tuemmler had shown by his actions that he rea-

(l to r): F. L. Garton, (chairman of Standardization Committee), Dr F. D. Tuemmler, W. H. Thomas (deputy-chairman of Standardization Committee), and H. Hyams.

lized that successful co-operation implied a real spirit of "give and take." The thanks of the Institute were due to ASTM Committee D-2 for having placed such an excellent ambassador as Dr Tuemmler at our disposal.

Dr F. D. Tuemmler, responding to the toast, said he had much enjoyed the co-operation and the hospitality of the past two weeks. In the U.S.A. there was a genuine desire to co-operate with IP in the field of petroleum testing. Any differences which existed could be settled by a co-operative programme. It was not to be expected that identical procedures could be arrived at immediately, as there was much background work to be done, but in the meantime technical equivalence of corresponding methods was a step which could be attained.

He pointed out that Committee D-2 held its meetings at approximately the same times each year and he looked forward to welcoming any representatives of IP Standardization Committee at these meetings.

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U.K. PETROLEUM CONSUMPTION

Figures published by the Petroleum Information Bureau on behalf of the U.K. Petroleum Industry Advisory Committee indicate that U.K. oil consumption (excluding bunkers) reached a new record level of 9,265,344 tons during January to June 1953, against 8,717,516 tons for the same period of 1952.

Premier motor spirit, which returned on 1 February, also reached a new record level of 1,078,298 tons of sales to dealers and commercial consumers in the first six months of 1953. Other grades of motor spirit amounted to 1,672,066 tons. Thus premier motor spirit accounted for some 40 per cent of all motor spirit.

Details from the returns are as follows:

U.K. Deliveries into Consumption of Petroleum Products (in tons) January to June

Product	1952	1953
Motor spirit (incl motor benzole)	2,648,727	2,750,358
Industrial spirits (incl industrial benzole)	43,792	46,305
White spirit	70,851	70,005
Kerosine		
Burning oil	297,368	300,285
Vaporizing oil	464,331	428,915
Total	761,699	729,200
Derv fuel	572,213	605,990
Gas, diesel, and fuel oils		
Inland trade		
Gas-diesel oil	842,379	879,842
Fuel oil	1,746,807	1,918,201
Total inland trade (excl refinery consumption)	2,589,186	2,798,043
Refinery consumption	606,113	706,898
Grand total inland trade	3,195,299	3,504,941
Lubricating oils and greases	374,874	383,555
Paraffin wax and scale	16,130	18,283
Propane and butane	22,854	24,783
Bitumen	374,278	355,883
Other products	636,799	776,041
Total all Products	8,717,516	9,265,344

Note: Deliveries for bunkers for ships engaged in the foreign trade are not included.

U.K. Motor Spirit Deliveries to Dealers and Commercial Consumers (in tons) January to June

	1952	1953
Dealers		
Premier grades	—	966,563
Other Grades	—	817,921
Total	1,675,400	1,784,484
Commercial consumers		
Premier grades	—	111,729
Other grades	—	854,145
Total	973,327	965,874
Total		
Premier grades	—	1,078,292
Other grades	—	1,672,066
Total	2,648,727	2,750,358

U.K. Production of Petroleum Products Ex Imported and Indigenous Crude and Process Oils (incl Shale) (in tons) January to June

Product	1952	1953
Motor and aviation spirit	2,308,803	2,941,632
Industrial spirits	1,309	1,144
White spirit	26,764	22,178
Burning oil	334,813	253,107
Vaporizing oil	10,135	41,097
Gas-diesel oil	1,958,409	2,046,227
Fuel oil	5,110,398	5,148,428
Refinery fuel consumption (ex own production)	597,593	694,275
Bitumen	371,518	339,900
Paraffin wax, scale, and slack wax	7,124	8,052
Lubricating oil	189,750	180,867
Propane and butane	13,312	12,968
Miscellaneous products and loss	258,799	412,153
Total	11,188,727	12,102,028

COUNCIL COMMENTARY

There was a large attendance at the first (September) Council Meeting of the new Session, with the President, H. S. Gibson, C.B.E., in the Chair.

The first concern of Council at this time of the year is the selection of a President for the next Session. Mr Gibson is, at present, serving his second year of office and he, together with the past Presidents, and the honorary officers of the Institute, will suggest a nomination to be put forward at the Annual General Meeting.

The Institute staged a very successful Summer Meeting at Buxton this year and has decided to hold another such meeting during 1954. It will be appreciated by Institute members that a considerable amount of work is entailed in organizing a meeting of this description. First, the venue of the meeting must be agreed and a hotel found which will accommodate the 150 or so people who may be expected to attend. Then, as these meetings are held in the late spring or early summer, bookings must be made a considerable time in advance and the decision on how many double and single rooms to reserve is a difficult problem for the General Secretary. Members will be interested to learn that Council has decided that the 1954 Summer Meeting shall take place at the seaside and preliminary enquiries are even now afoot.

The technical side of the conference in its turn requires a great deal of thought and organization. Publications Committee has to decide on a suitable theme for the meeting and then, most difficult of all, to select authors for the papers required. These papers must be in the Editor's hands sufficiently early for pre-prints to be prepared, and thus the selection of authors must be expeditious.

The Institute should congratulate itself that its corporate membership now exceeds 3000. It is confidently anticipated that with the growth of the petroleum refining industry in the U.K., membership of the Institute will see significant increases within the next few years.

Of considerable interest to those engaged on the distribution of the industry is the news that the Institute has decided to form groups within the organization to consider various aspects of the petroleum industry and to bring together all those people with interests in a particular field. The first group to be formed will embrace Marketing, Distribution, Storage, Transportation, and Economics, and O. F. Thompson, O.B.E., has agreed to be chairman of this group for one year. He is holding the inaugural meeting at 26 Portland Place, on Wednesday, 7 October, after which a paper will be given on "The International Economic Setting of the World Oil Industry" by G. P. Glass.

Dr F. D. Tuemmler of the ASTM Committee D-2 and who is well known to many members of IP Standardization Committee and its sub-committees has spent two or three weeks in Britain and has attended a series of meetings with various groups of the Standardization Committee. There is no doubt that as a result of this meeting, ASTM/IP co-ordination will be considerably advanced.

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COUNCIL ELECTIONS 1953

Members are reminded that, under By-law 72, all nominations for the Council Elections in 1954 must be received by the General Secretary not later than 31 December 1953.

Applications must be made on the special Council Election form, proposed by a corporate member and supported by six corporate members. These forms can be obtained from the General Secretary, 26 Portland Place, London, W.1.

AROUND THE BRANCHES

LONDON, SCOTTISH, SOUTH EASTERN

London Branch

On 22 September, at Manson House, members had the pleasure of welcoming the branch lecturer, Mr E. A. Evans, and of listening to his address entitled, "Lubrication—Chemist or Engineer."

Mr Evans began by advising the young technician, whether chemist or engineer, to choose an objective, perhaps membership of a corporate body, and to pursue this objective without deviation. In this way a standard could be achieved which guarantees a minimum financial reward.

"Science," Mr Evans went on to say, "is quite compatible with the arts. Voltaire was a Master of Science, and Keats and Goldsmith were physicians. There is no reason, therefore, why reports or theses should lack artistic portrayal or readability. It was the readability of Darwin which ensured his widespread and speedy acceptance. Following such examples the young scientist should grace his technical data with as much art as possible."

Developing his theme, Mr Evans gave a *résumé* of science through the ages from the time of the pyramids to present-day nuclear fission. "The modern age," said Mr Evans, "dated from the middle of the 16th century and was marked by the achievements of Watt, Stephenson, Otto, Daimler, Diesel, and many others. It was the development of the machine, in all its forms, which focused attention on lubrication. Names, such as Beachamp Tower, Osborne Reynolds, Sommerfeld, Michell, and others, became famous as the exponents of the principles of boundary and fluid film lubrication.

"The lubricating properties and effects of metal soaps have been known for some time. Less appreciated, perhaps, are the effects of transition temperatures." Mr Evans cited as an example a phosphated metal surface which gave a coefficient of friction of 0·7. "A similar unphosphated metal surface, coated with paraffin wax, gave a figure of 0·24. However, when the phosphated metal was treated with wax, a friction coefficient of 0·17 was obtained, thus demonstrating the importance of the lubricant in relation to the type of metal surface. It is such developments that demonstrate the need for engineering and chemical co-operation."

Mr Evans concluded with various personal reminiscences which exemplified the desirability of co-ordinating chemical and engineering experience in solving lubrication problems. Perhaps, particularly since the advent of additives, which were far from simple compounds and whose discovery needed a chemical flair, the chemical mind was better adapted to the development of lubricants. Synthetic lubricants, too, were in the chemist's province.

An appreciation of Mr Evans' address was ably made by Mr A. J. Goodfellow and heartily endorsed by the audience. Afterwards a number of members attended the usual informal dinner at the Bolivar at which the speaker was the guest of the branch.

Scottish Branch

A meeting was held in the Scottish Oils' Recreation Club, Grangemouth on 24 September.

Mr J. M. Caldwell, J.P., chairman of the branch, presided and introduced the lecturer, Dr D. A. Howes. He said that many present had known Dr Howes since he joined the Company as a research chemist at the Anglo-Iranian Oil Company's Research Station at Sunbury. He had held various posts in Abadan and New York, and was now Technical Manager at the National Oil Refineries, Llandarcy. Because of Dr Howes' wide experience in the technical and administrative side

of the oil business, they were looking forward to his paper, entitled "Some Ahead Problems in the Petroleum Industry."

Dr Howes said that although Western Europe's leading industries are based on coal, it is by far the most important oil marketing area of the free world outside North America, and this year will have a demand for petroleum products slightly more than one-third of the quantity required by the whole free world outside North America. On the other hand, with its population of about 280 million, its oil requirements are only about one-fifth of those of the U.S.A., with its population of 160 million.

The demand for petroleum products in Western Europe has increased considerably during the post-war years and is estimated to reach no less than 85 million tons in 1956, whereas in the period immediately before the war it was about 31 million tons. To meet this large demand the petroleum refining capacity in Western Europe has been considerably increased during the past few years and is expected to reach over 90 million tons in 1954.

There are however important differences between the demands for individual petroleum products in Western Europe and those existing in the U.S.A. and other parts of the world. These differences necessitate a choice of refinery processes which allows the production of products in proportions substantially different from those required in the U.S.A. and several important technical problems are involved. Thus it is necessary to produce a high yield of kerosine, aviation turbine fuels, gas oils, diesel fuels, and fuel oils, while the demand for gasoline is relatively much less than in the U.S.A. The technical problems involved in meeting these market requirements were briefly discussed.

Dr Howes also made reference to the continuous effort which must be applied to the manufacture of petroleum products of higher quality. The petroleum industry has a proud record in this respect and has so far proved equal to all demands made upon it. It will also meet all future demands but the problem of producing higher quality products at economic costs requires constant attention.

Many members took part in the discussion which followed, and Dr Howes was accorded a very hearty vote of thanks on the call of the chairman.

South Eastern Branch

On 6 October, Mr G. C. Silsby of Irano Products Ltd. gave a talk which covered the whole field of detergents, including their history, manufacture, and application.

Mr Silsby said that the properties of detergents (the word having been derived from the Latin and meaning scouring or cleaning) were known many years ago, the first of which originated from vegetable oil. However, detergents, as we know them today, are of comparatively recent origin, rapid strides having been made during the past eight years. In the U.S.A., for instance, in 1952, 43 per cent of the whole of the soaps and detergents sold were, in fact, detergents, and in 1953 this figure rose to 53 per cent, thus indicating that the sale of detergents had become greater than the sale of soap.

Mr Silsby then described the various types of detergents and the applications to which all these types were applied, and that whilst detergents were not the entire answer to the "Maiden's Prayer" they had their uses, which were many and varied.

The talk was followed by a lively discussion, in which the subject of household detergents was prominent. It had been proved that many of the fears that had grown up with the use of detergents were psychological and not based on fact. Mr Silsby pointed out that, in his opinion, the old war-time title of "Soap

substitute" should be abolished, as this undoubtedly had a deterrent effect.

During the discussion the subject of river pollution, caused by the addition of detergents in water drainage, was ventilated, and although much has been said about the danger to the fish life in rivers, Mr Silsby stated that one detergent manufacturer had had fish living in freshwater tanks which contained a certain quantity of detergent, without any apparent ill effect. Mr Silsby mentioned another interesting use to which detergents were applied in the U.S.A. which was the fattening of poultry. Apparently, it has been proved that the addition of detergent to the feeding materials has cut down the fattening period considerably.

It was evident by the questions and subsequent discussion that the talk had been of very great interest, and all present went away knowing much more about detergents than when they arrived.

A vote of thanks was given by the chairman, Mr N. W. Grey, to Mr Silsby for the very excellent manner in which he had dealt with his subject.

* * *

COMPANY PRODUCTION

	Aug. 1953 *Tons*
Qatar Petroleum Co. Ltd.	378,646
Kuwait Oil Co. Ltd.	3,677,843
Iraq Petroleum Co. Ltd. (Kirkuk)	2,005,595
Basrah Petroleum Co. Ltd. (Zubair)	277,307
Mosul Petroleum Co. Ltd. (Ain Zalah)	108,942

The 1952-53 crude oil production of the Trinidad Petroleum Development Co. Ltd. was 3,424,409 brl (3,091,175 brl in 1951-52).

	Sept. 1953 *Brl*
Kern Oil Co. Ltd. California	105,664
Trinidad	82,224
Trinidad Petroleum Development Co. Ltd.	272,046

★ ★ ★

LABOUR STATISTICS FOR THE U.K. PETROLEUM REFINING INDUSTRY

The following figures are taken from the September 1953 issue of the *Ministry of Labour Gazette* (cf. previous figures given in the *I.P. Review* (1952, **6**, 167)).

Figures in bold type are the averages for all the industries covered by the tables.

	Men (21 and over)	*Youths and Boys*	*Women (18 and over)*	*Girls*	*All Workers*
No. of wage-earners covered by remuneration statistics	16,269	687	793	25	17,774
Average earnings in last pay-week in April, 1953	198/3	82/3	105/6	—	189/5
	185/11	**77/7**	**100/3**	**62/6**	**157/7**
Average number of hours worked in this pay-week	48·8	44·7	44·0	—	48·5
	47·8	**44·5**	**42·0**	**42·7**	**46·2**
Average hourly earnings in this pay-week (pence)	48·8	22·1	28·8	—	46·9
	46·7	**20·9**	**28·6**	**17·6**	**40·9**

	Males	*Females*	
Numbers employed (July 1953)	32,400	6,200	38,600
Numbers unemployed (at 10 Aug. 1953)	232	27	259
Labour turnover rate (5 weeks ended 27 June 1953			
No. of engagements per 100 employed	1·7	2·0	1·8
	2·3	**3·6**	**2·7**
No. of discharges and other losses per 100 employed	1·2	1·3	1·2
	2·3	**3·5**	**2·7**

OIL COMPANIES' ORDERS IN THE U.K.

The Oil Companies Materials Secretariat furnish the following statement of value of orders placed in the United Kingdom by oil companies during April-June 1953:—

	£
Geophysical and other exploratory equipment, etc.	3,800
Specialized equipment for oil drilling and production, including oil casing, tubing, etc.	1,714,800
Specialized equipment for oil refineries, etc. (not including pumps and valves)	1,711,200
Drum and can-making, filling and cleaning equipment, kerbside pumps and other oil metering and dispensing equipment, etc.	201,000
Railcars, road tankers, aircraft refuellers, etc.	110,800
Drums, drumsheets, and tinplate	887,000
Tankage (including tank fittings)	271,900
Tubulars, pipe fittings, and valves (ferrous and non-ferrous)	1,972,200
Pumps, (excluding slush, oilwell, and kerbside)	268,200
Boilers, boiler house plant and accessories, etc.	191,900
Electrical equipment—motors, generators, transformers, etc.	1,077,600
Instruments, meters, gauges, etc.	180,800
Prime movers and compressors	342,200
Machine and hand tools, welding and miscellaneous machinery, and stores	1,366,200
Ferrous and non-ferrous plates, sections, sheets, and bars	678,100
Automotive equipment, all types	939,600
Laboratory equipment and chemicals, including hospital and medical supplies	132,600
Bulk chemicals, catalysts, barytes, etc.	2,757,700
Cement and other building materials and hardware, including timber	672,300
Commissary, general requisites for office, warehouse, household, club and sports, etc.	986,200
	£16,466,100

* * *

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FORTHCOMING MEETINGS

The Institute

The Friction of Solids. F. P. Bowden, Sc.D., F.R.S. (*University of Cambridge*). Redwood Lecture. At 26 Portland Place, London, W.1., 5.30 p.m. (*tea*, 5 *p.m.*), **2 December.**

Stores Control. R. C. H. Toye (Anglo-Saxon Petroleum Co.). At 26 Portland Place, London, W.1., 5.30 p.m. (*tea* 5 *p.m.*), **9 December.**

Fawley Branch

Annual Dinner. At Esso Recreation Club, Holbury, 7.30 p.m., **4 December.**

Prospecting for Oil. C. A. E. O'Brien, B.A., F.R.G.S., F.R.S. At Esso Recreation Club, Holbury, 7.30 p.m., **11 December.**

London Branch

Calibration of Tanks and Tankers. W. F. Jelffs. At 26 Portland Place, London, W.1., 6 p.m. (*tea* 5.30 *p.m.*), **19 November.**

Northern Branch

The Blending of Lubricating Oils—Continuous and Batch Methods. R. C. Cobley and L. Soulal. At Engineers' Club, Albert Square, Manchester 2, 6.30 p.m., **17 November**

Scottish Branch

International Standardization of Bulk Petroleum Measurement and Quality Testing. H. Hyans (Fellow). At Scottish Oils Ltd., Recreation Hall, Grangemouth, **10 December.**

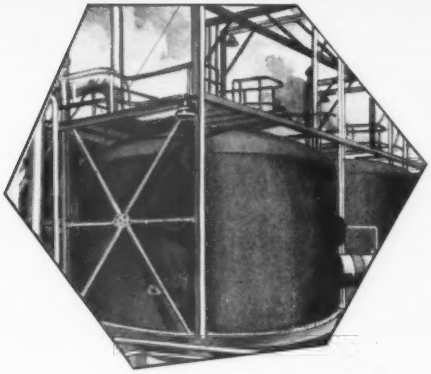
South Eastern Branch

Brains Trust. At King's Head Hotel, Rochester, 7.45 p.m., **1 December.**

South Wales Branch

Services for Refinery Operations. G. D. Curtis, B.Sc., A.M.I.E.E. At N.O.R. Training Centre, Llandarcy, 5.30 p.m. (*tea* 5 *p.m.*), **3 December.**

Manufacture and Applications of Grease. J. B. Matthews, B.Sc., PH.D., F.R.I.C. Joint Meeting with the Royal Institute of Chemistry at Grosvenor Hotel, Chester, 7.30 p.m., **16 December.**



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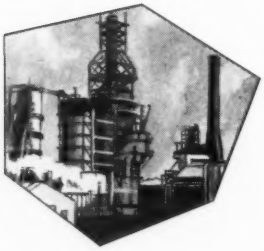

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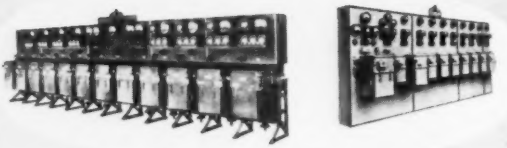

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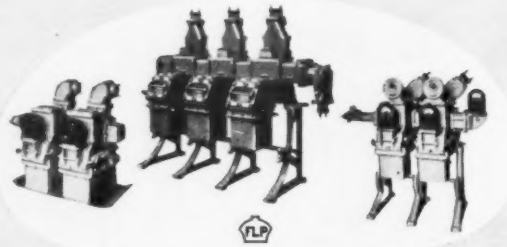

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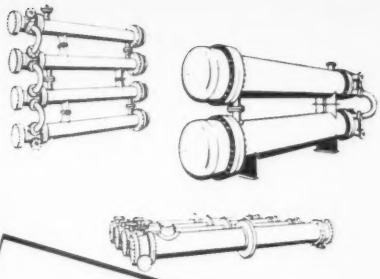

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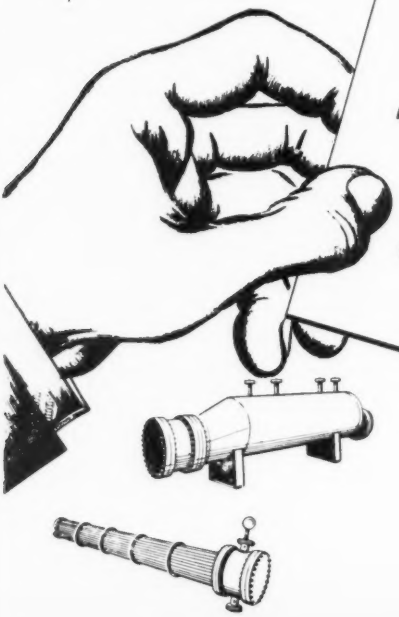

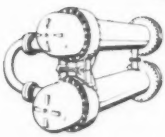

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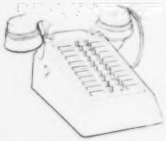

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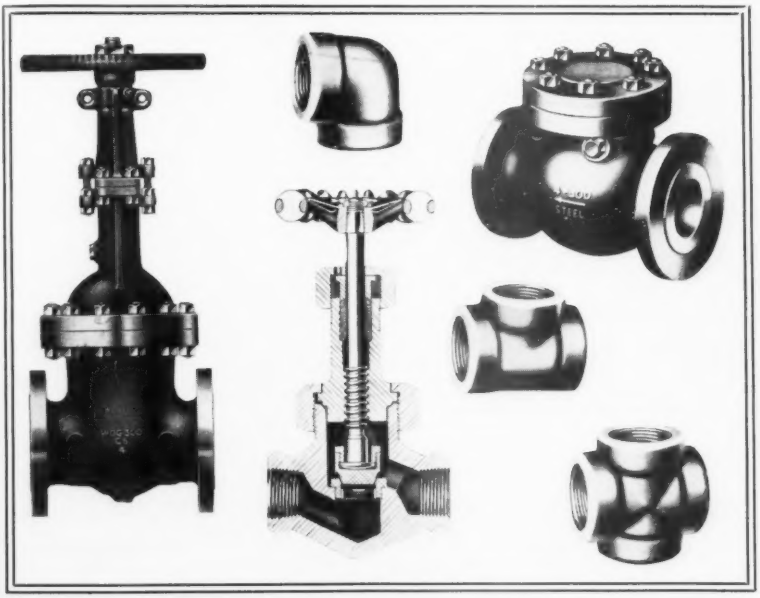

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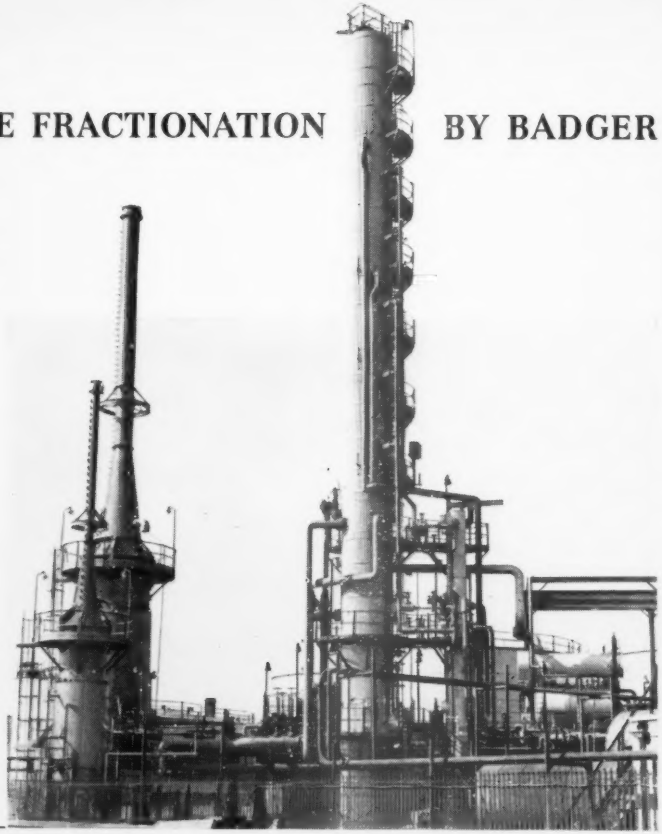

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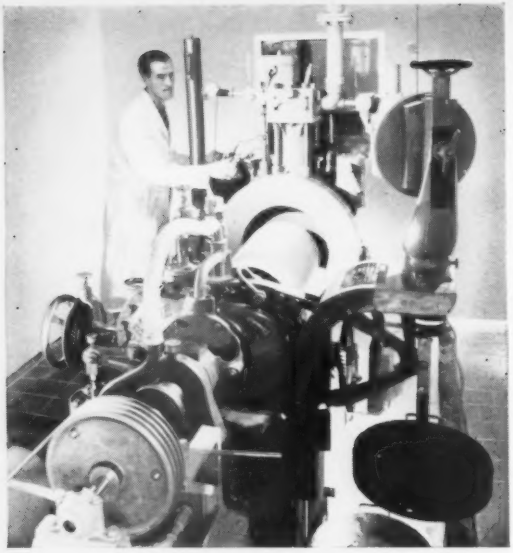

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